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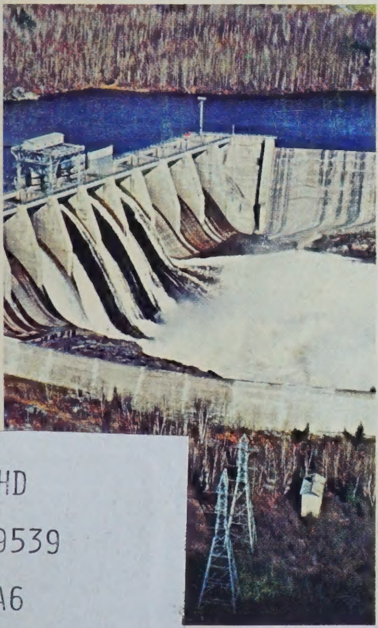
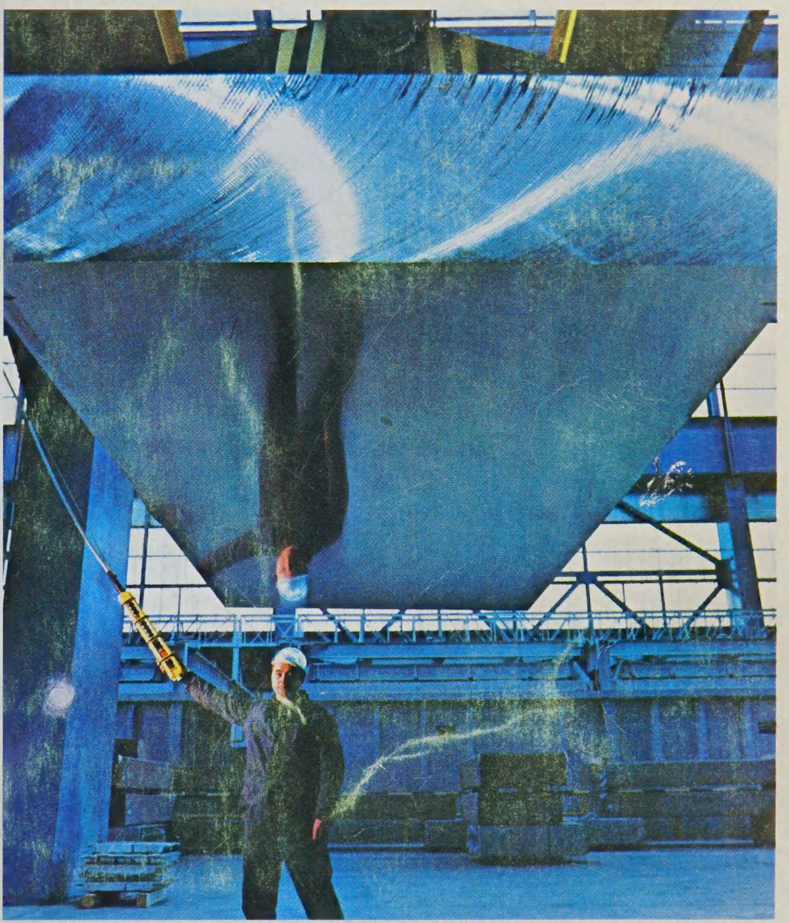
aluminum and power

in the Saguenay Valley





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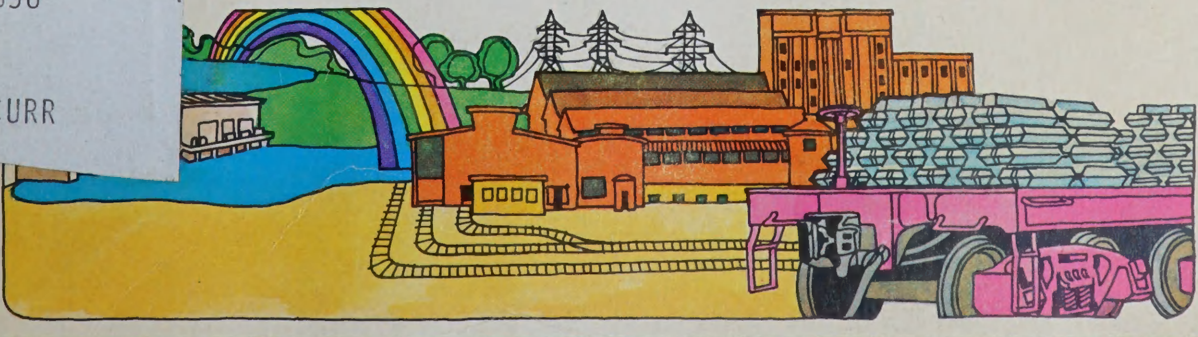

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aluminum and power

in the Saguenay Valley

by P. G. Burpee

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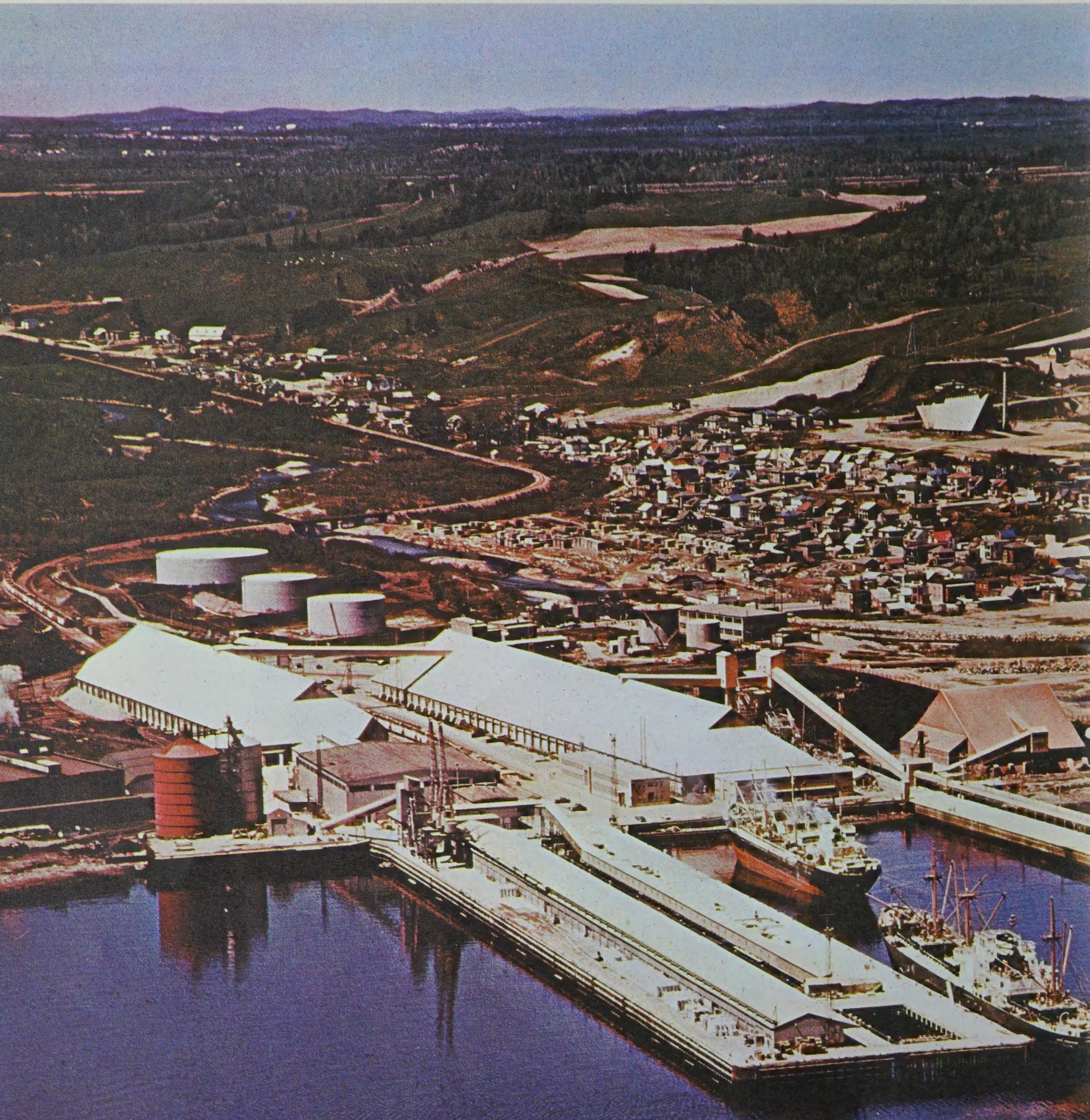

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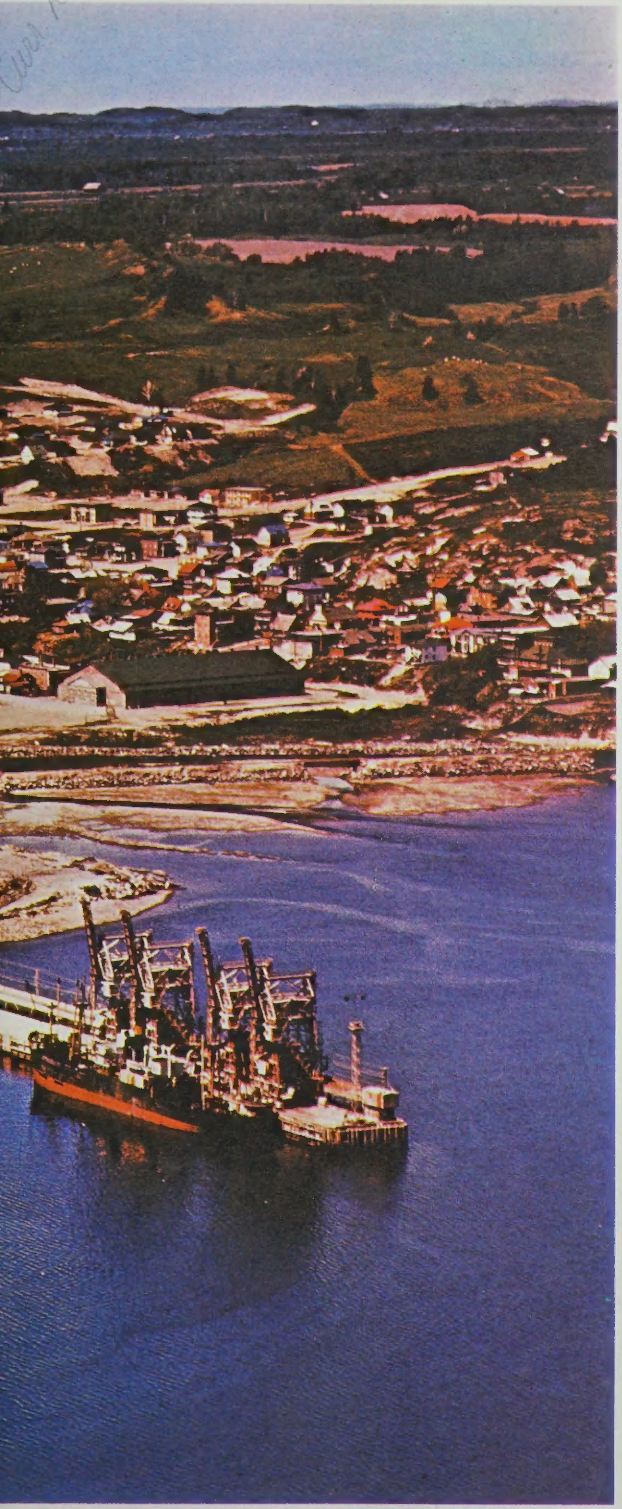

Here Comes the Bauxite!

The busy port shown in the photo is Port Alfred, at the head of navigation of the Saguenay River. The main cargoes arriving at the docks shown here are bauxite and alumina, from which aluminum is made. These are taken by rail about twenty miles upriver to Arvida, where the largest aluminum smelter in the world is located.

DO

1. Locate the Saguenay River on the strip map on page 4. What province is it in?
2. What does the term "head of navigation" mean?
3. Which dock in the photo is a loading dock? Which is an unloading dock? How can you tell?
4. Why are the conveyer belt and the storage sheds enclosed? Why are the storage sheds so large?
5. Note the ship being unloaded. How many unloaders are there? What is the importance of unloading the ship quickly?
6. a. How far is Port Alfred from your home town? (Measure the direct distance.)
   b. Plan a route from your home town to Port Alfred, using at least two different means of transportation. In what general direction would you be travelling?

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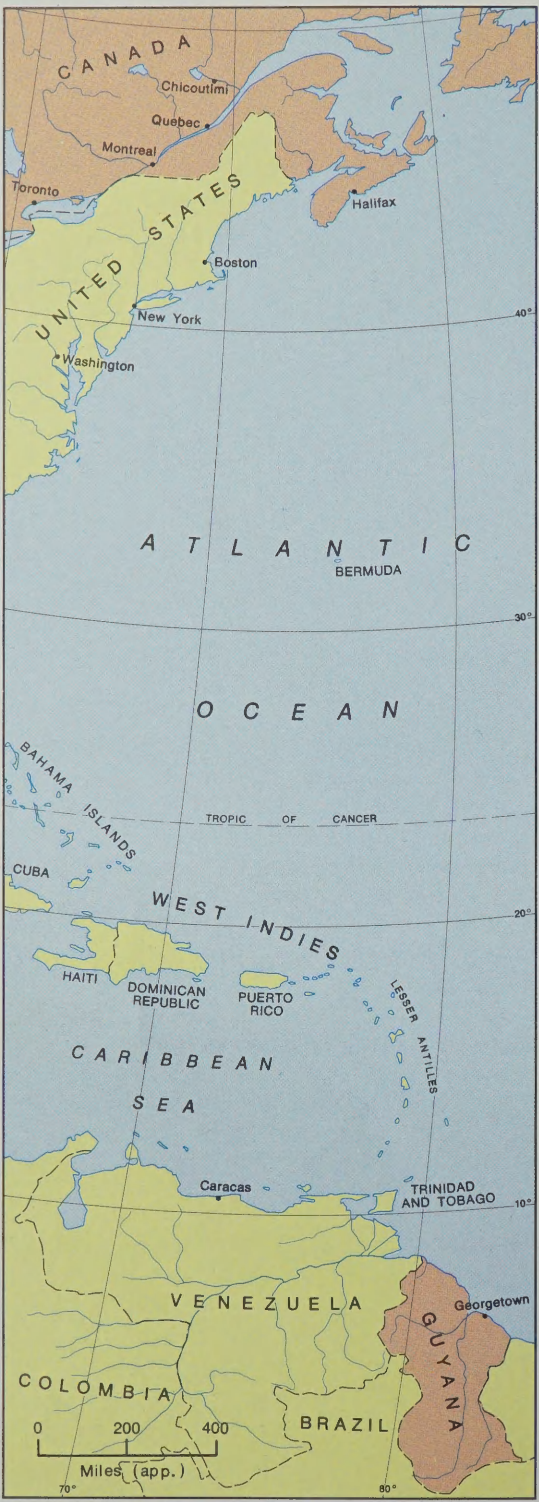
Compare this photo with the one on page 7, and suggest one reason why Arvida was chosen as the site of the aluminum plant, rather than Port Alfred.

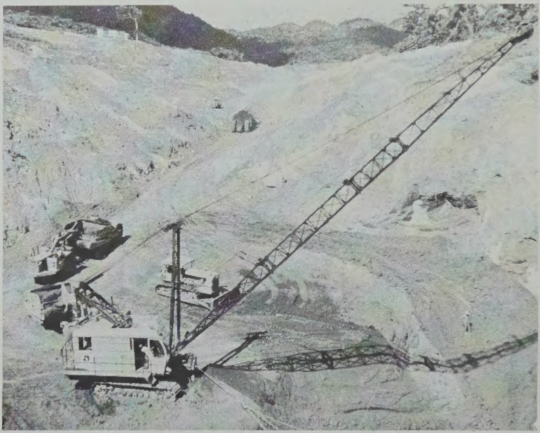


The bauxite that passes through Port Alfred on its way to Arvida comes from Guyana, a small country on the north coast of South America. The hot, humid climate helped to form this soft, almost claylike ore.

Does it not seem strange that aluminum is made in Canada where there is no ore, but is not made in Guyana where the ore is plentiful?

DO

1. Locate Guyana on the strip map. Trace the route that the ore takes from the mine in Guyana to Port Alfred. How many miles is the sea journey?
2. A typical ship carrying bauxite has an average speed of 15½ miles per hour. How many days will it take to go from Guyana to Port Alfred?



1. With the help of reference books, define "ore."
2. a. What type of mine is shown in the photo?
b. How is it different from other types of mines?
3. What problems can weather conditions create for open-pit mining: in Canada? in Guyana?

RECIPE

Take 20 tons of bauxite from Guyana, grind, filter, and dry it, to make alumina. Then in a pot heat about a ton of fluorspar from Newfoundland and cryolite from Greenland, to about 1000°F. Into this hot mixture pour the finely powdered alumina. Turn on the electricity. As the aluminum settles, drain it off from the bottom of the pot and remove it to a holding furnace to simmer for several hours. Season with small quantities of zinc, copper, manganese, etc., to suit individual requirements. Pour into a mold and allow to set. When set, can be moved to rolling mill and rolled out like pie dough. Will make one 5-ton ingot.

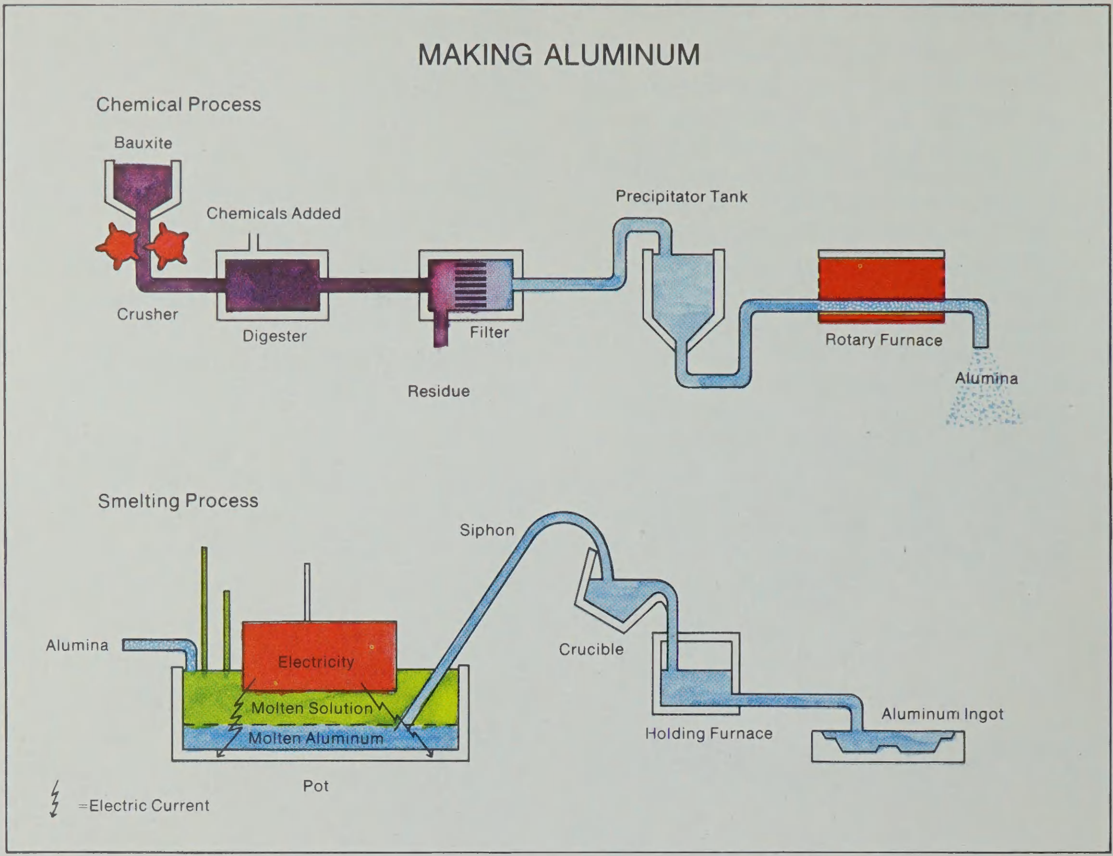
How Aluminum Is Made

The "recipe" on this page, while it may appear rather fanciful, is perfectly accurate. Perhaps, however, it does call for a word of explanation. Making aluminum metal from its ore, bauxite, involves two processes.

Refining alumina from bauxite: a chemical process

The first, a chemical process, removes the impurities from the bauxite. The ore is crushed, mixed with chemicals, heated under pressure, filtered, and finally dried, to produce the fine white powder called alumina, which is a combination of oxygen and aluminum. This chemical process can be done almost anywhere, and more and more is being done near the sources of the bauxite. Guyana processes much of its bauxite and exports alumina.

This huge bucket wheel excavator in Guyana chews its way through two hundred feet of sand overburden to get at the bauxite.



MAKING ALUMINUM

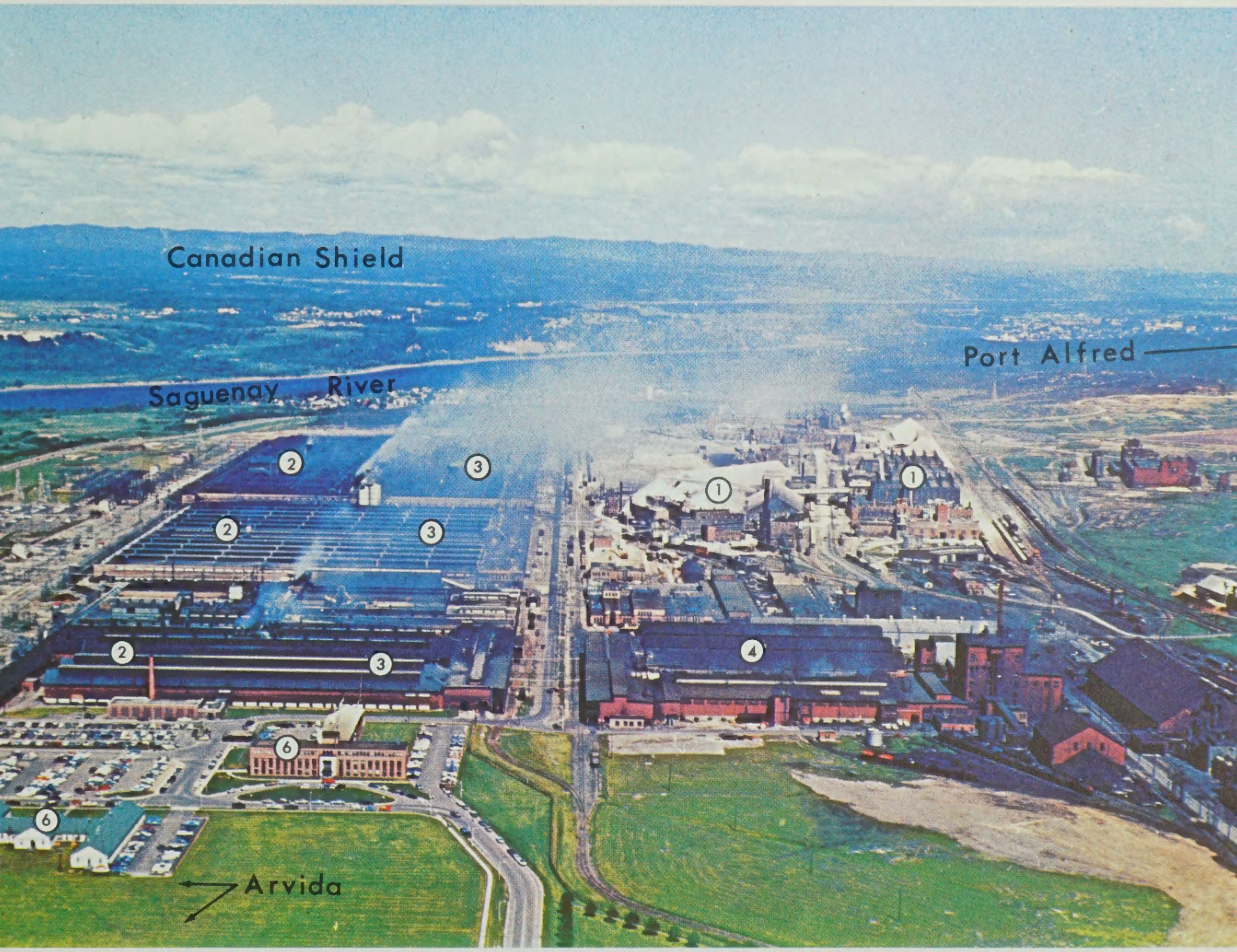
DO

1. It takes about two tons of bauxite to make one ton of alumina. What is the obvious advantage of doing the first part of the processing near the source of the ore?
2. The aluminum plant at Arvida was built in 1926. At that time it was more practical to do the chemical part of the processing at Arvida. Suggest reasons why bauxite is still processed at Arvida today.

Separating aluminum metal from alumina: a smelting process

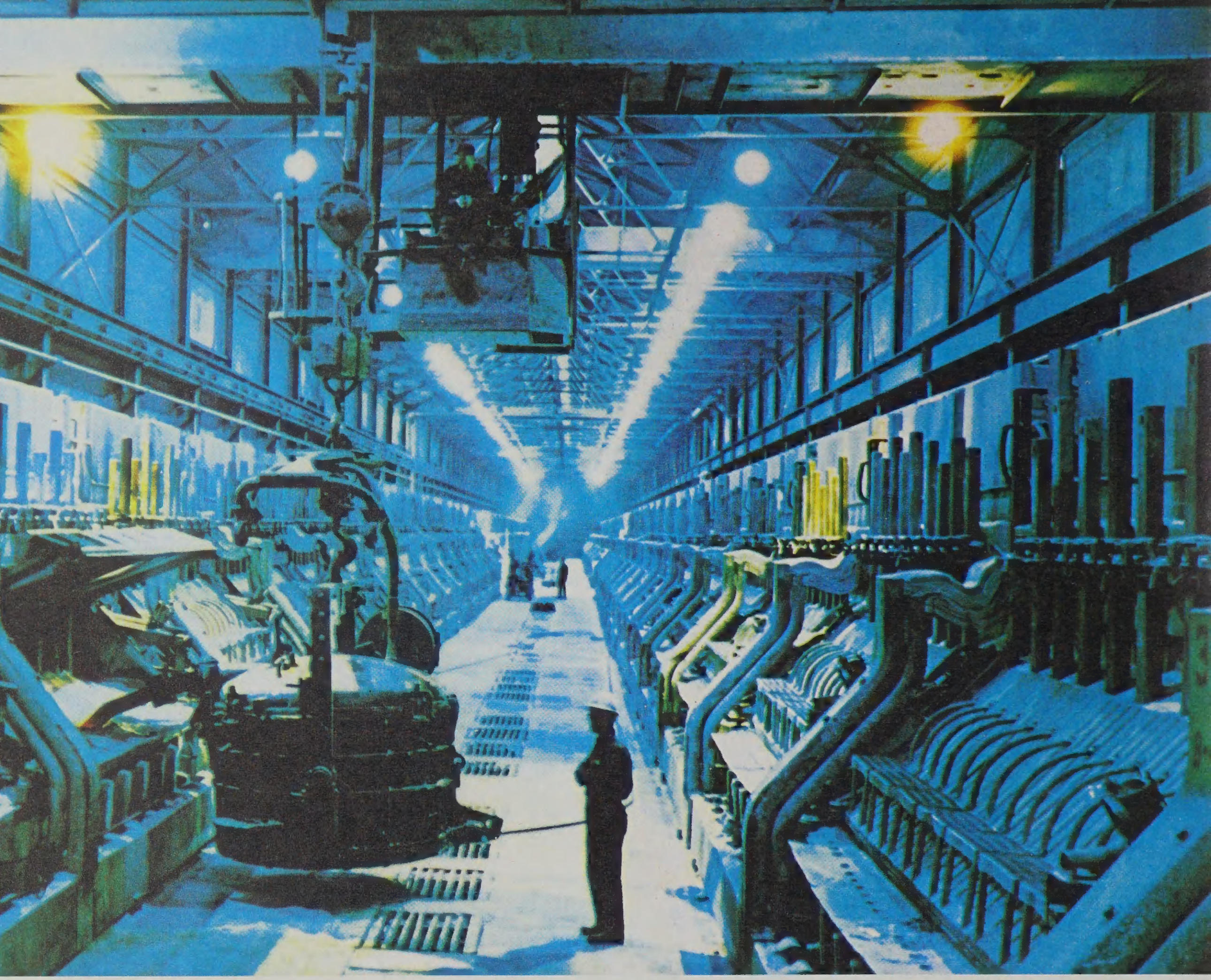
The second process is an electrical one, requiring great quantities of electricity. Because alumina does not conduct electricity, it must first be dissolved in a molten material that does. This material is called an *electrolyte*. The electrolyte is put into large *electrolytic cells*, called "pots." These are arranged in long rows of perhaps a hundred or more. How many pots are in the rows shown in the photo? As a powerful electric current passes through the electrolyte, the alumina is separated into aluminum and

The aluminum plant at Arvida: (1) alumina-processing area, (2) potlines, (3) holding furnaces, (4) storage of ingots, (5) electrical transformers, (6) administration. Note also the power transmission lines on the left. Try to draw a sketch map of this plant. Label the various areas, and indicate with a line and arrowheads the course of the aluminum through the plant.



oxygen. The metal sinks to the bottom of the pot and is then drawn off by means of a siphon and taken to a *holding furnace*.

In the holding furnaces, the aluminum metal is kept at high temperatures for two or three hours to improve its quality. Also, other metals may be added to make aluminum *alloys* with various characteristics. For example, the addition of small amounts of copper and zinc will make the aluminum much stronger. Finally, the pure aluminum or the alloy is poured into molds and cooled.



A potline in the Arvida plant. Aluminum is being siphoned from the bottom of a pot into the crucible. How is the crucible moved about from pot to pot and then to the holding furnace?

DO

One of the materials used in the smelting of aluminum is *cryolite,* which is found in Greenland. Locate Greenland on a map in your atlas, and estimate the distance from its southern tip to Port Alfred.

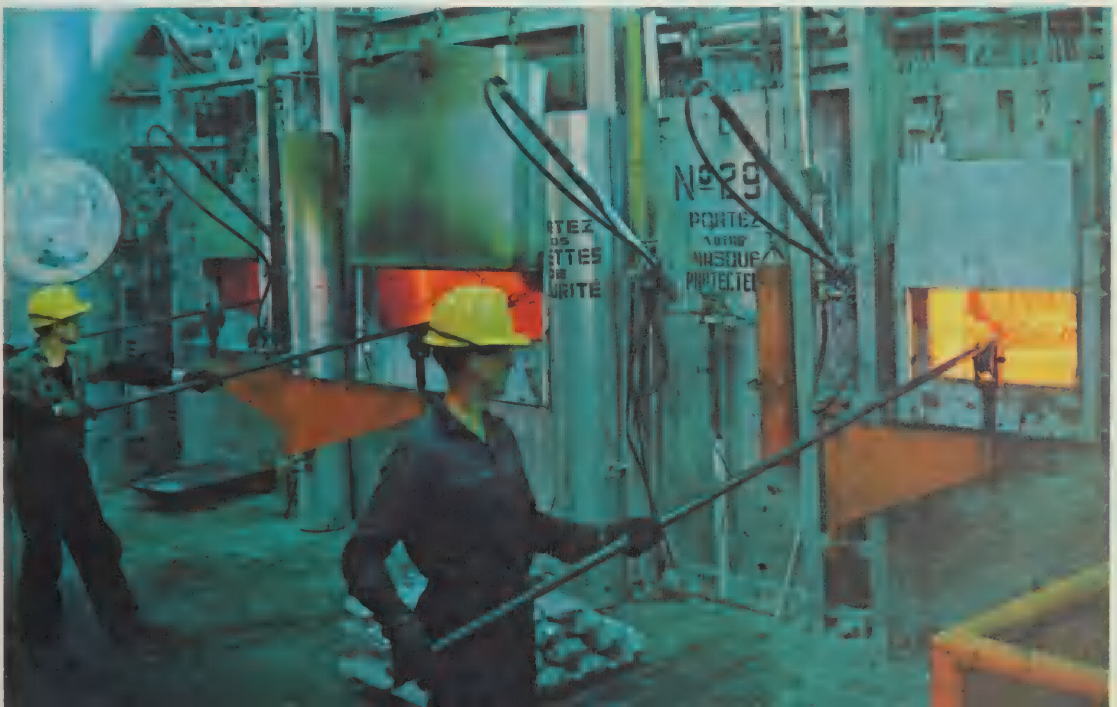
Aluminum Ingots and Their Many Uses

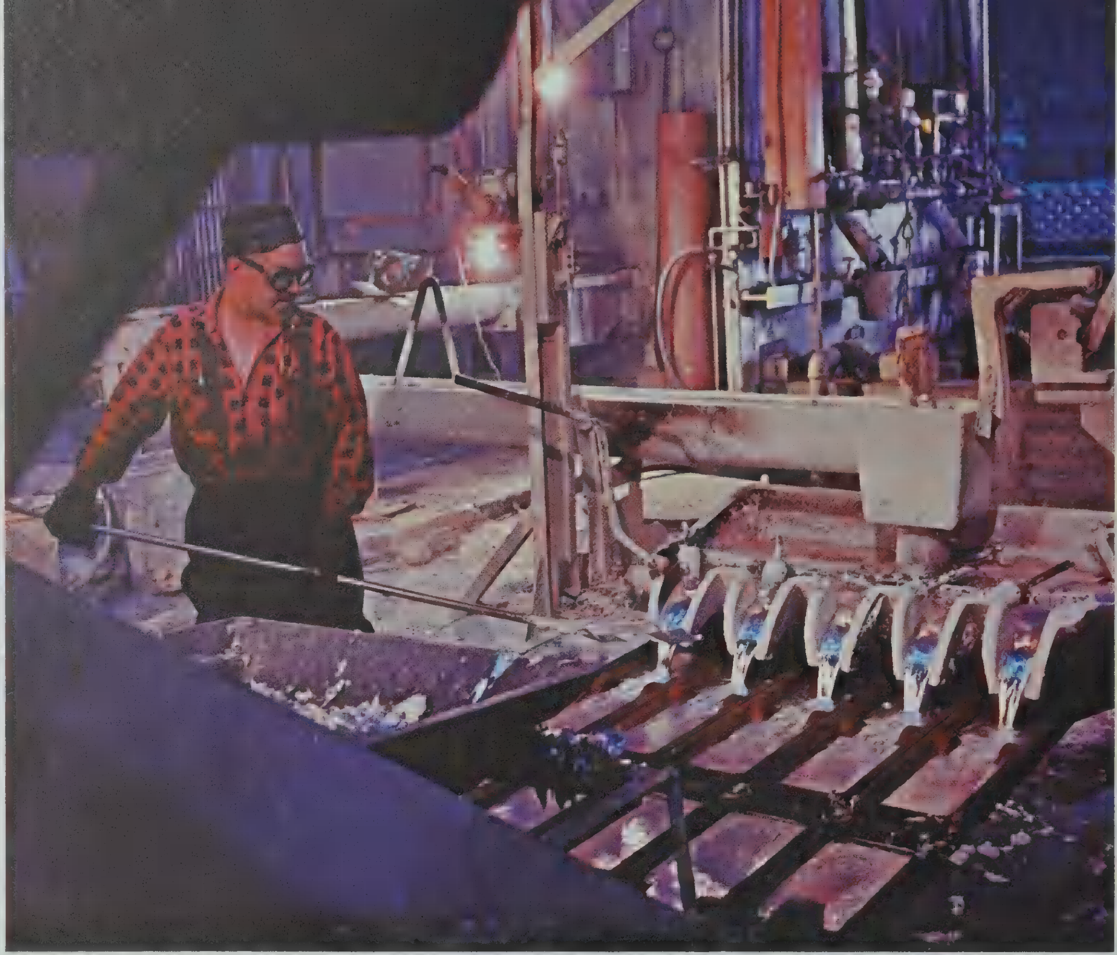
The three shapes of aluminum shown in the photos are known as *ingots*. It is in the form of ingots that the aluminum leaves the Saguenay Valley, either by rail from Arvida or by ship from Port Alfred, to be manufactured into a great variety of products. The huge sheet rolling ingots are rolled into plate, sheet, or foil, just as pie dough is rolled from a ball into thin pie crust. Large steel

Extrusion ingots. Storm window frames, garden chair frames, ladders, street light poles are some of the products that are made from extruded aluminum. Can you think of other examples?

A sheet rolling ingot. The mold for this type of ingot has a movable bottom. As the mold is filled, the bottom slowly drops. This helps to minimize impurities in the ingot.

A holding furnace at Arvida. With their long poles, these workers are removing the crust that forms on the molten metal. Why are they wearing hard hats and goggles? Why are the signs not bilingual?





Molten aluminum flows in a continuous stream into molds that move past on a belt. Further on, the belt turns under and the ingots fall out. The company's own name for these ingots is "Trilock" ingots. Find them in the photos on page 11 and at the bottom of page 9 and try to account for the name.

rollers play the part of the rolling pin, gradually squeezing the metal thinner and thinner, and longer and longer.

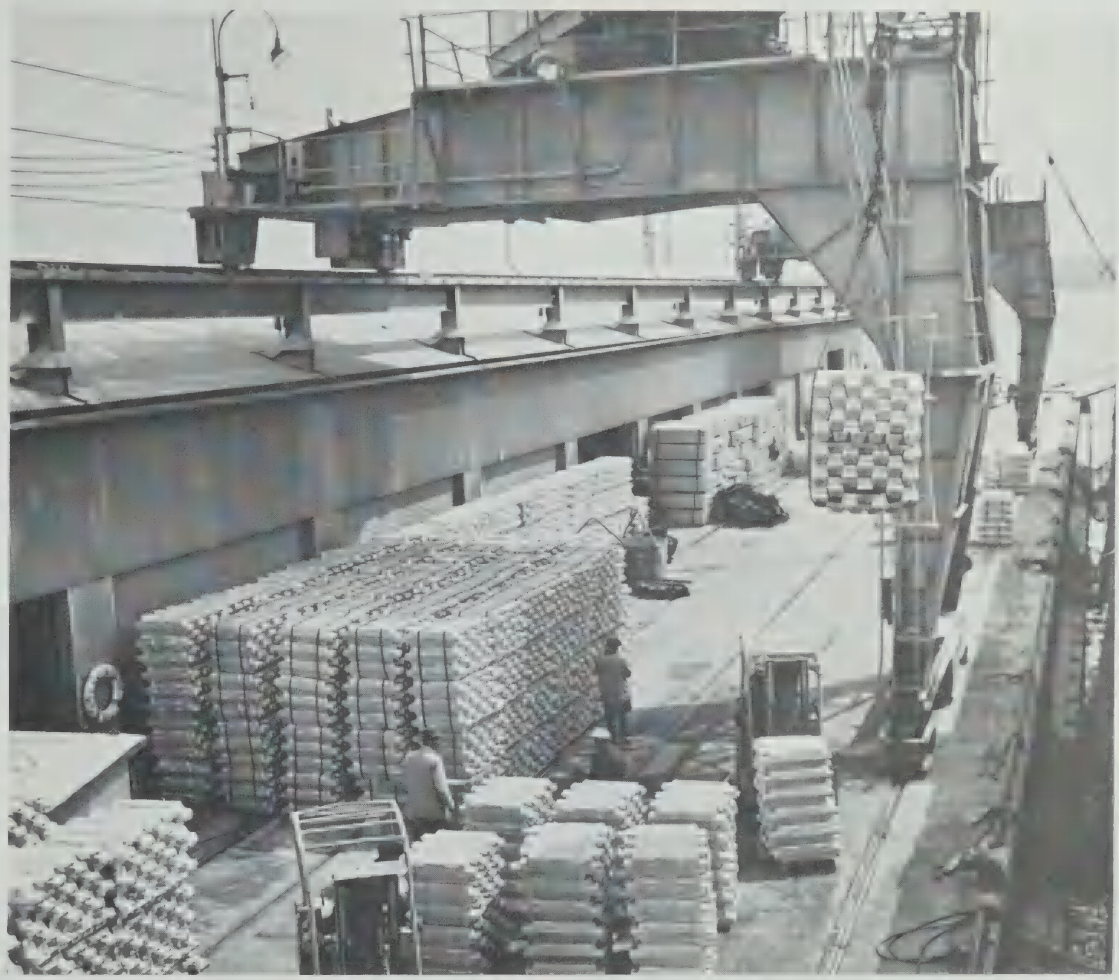
The cylindrical extrusion ingots are forced through an extrusion press, much as frosting is forced, in various fancy shapes, through the nozzle of a cake decorator. A *die* determines the particular shape in which the aluminum comes from the press.

The stacking ingots come in two sizes: thirty-five and fifty pounds. They are melted and used in a wide variety of products.

DO

1. Of the various jobs shown in the photos on these two pages and pages 8-9, which one would you prefer? Why? What other kinds of jobs would be available at the Arvida plant? (You will find the photo on page 7 helpful.)
2. In casting the sheet rolling ingot especially, great care must be taken to

Loading ingots at Port Alfred. How were the ingots brought to Port Alfred? What route would the ship take to reach the manufacturing centers on the Great Lakes? Those along the eastern coast of the United States?



keep the molten metal free of air bubbles. Why? What effect would air bubbles have when the ingot was rolled into foil?

3. A sheet rolling ingot such as the one shown in the photo on page 9 might measure 10 feet by 8 feet by $1\frac{1}{2}$ feet.

a. How many cubic feet of aluminum would such an ingot contain?

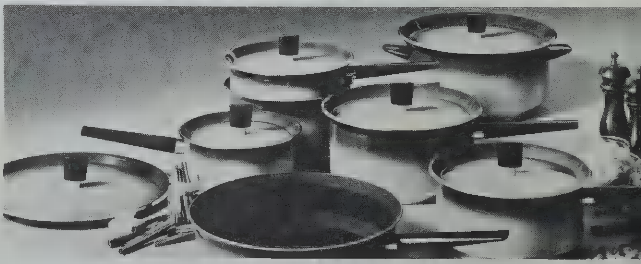
b. If 1 cubic foot of aluminum weighs 170 pounds, about how many tons would the ingot weigh?

4. What advantages and what problems would there be in making such huge sheet rolling ingots and in transporting them to a rolling mill in Kingston, Ontario, for example?

Some of the *properties* or qualities of aluminum are as follows:

it is very light in weight;
it is easy to work with: can be sawn, cut, shaped;
it will take a high polish;
it conducts electricity well;
it conducts direct heat efficiently;
it is a good reflector of radiant heat;
it is highly resistant to corrosion.

1. Check with a dictionary to make sure you understand the properties listed. Also look up the word "rust" to be sure that you know why aluminum makers and buyers need not worry about rust.



2. Make a list of the products shown on these two pages, and for each product decide which property or properties of aluminum would be of advantage. Consider not only the product itself, but also how it is made and where it is used. (Far upper right: a screen for floor-to-ceiling windows; far lower left: golf trophies. Above is the Lunar Module of Apollo 9, ready for a lunar landing. Its cabin is made of aluminum $^1/_{16}$ inch thick; its outer aluminum skin, enclosing wiring and plumbing, is about the thickness of heavy aluminum foil; its landing struts have shock absorbers of honeycomb aluminum, which will slowly crumple with the shock of landing.)

Aluminum in Canada

About 85 percent of the aluminum that Canada produces is exported, mainly to industrial regions in Europe and the United States, to be manufactured into finished products. This makes the aluminum industry unusual among Canadian industries in two ways: the ore is not found here, and only about 15 percent of the metal goes to rolling mills or other fabricating plants in Canada; the rest is exported. What is the reason, then, for such a large smelter being located at Arvida?

Aluminum and Electricity

You will recall from the section on the smelting of alumina that this process requires great quantities of electricity. To have a better idea of how much is required, do the following exercise.

DO

1. Find out, if you can (if you live in an apartment you probably cannot), how much electricity, measured in *kilowatt-hours* (abbreviated kwh), your home uses in a month. (Most bills are for two or three months.) Collect enough figures from the class to arrive at an average figure. Then multiply this figure by 12 to find out how much electricity an average home requires in a year.
2. To produce 1 ton of aluminum from alumina requires 16,000 kwh. How many homes would this supply for a year?
3. The aluminum smelter at Arvida produces about 375,000 tons of aluminum a year.
   a. How much electric power is needed for the smelter in a year?
   b. How many homes would this amount of electricity supply?
   c. At 5 persons per home, what would be the population of this "city"?
   d. How many cities are there in Canada with this many people?

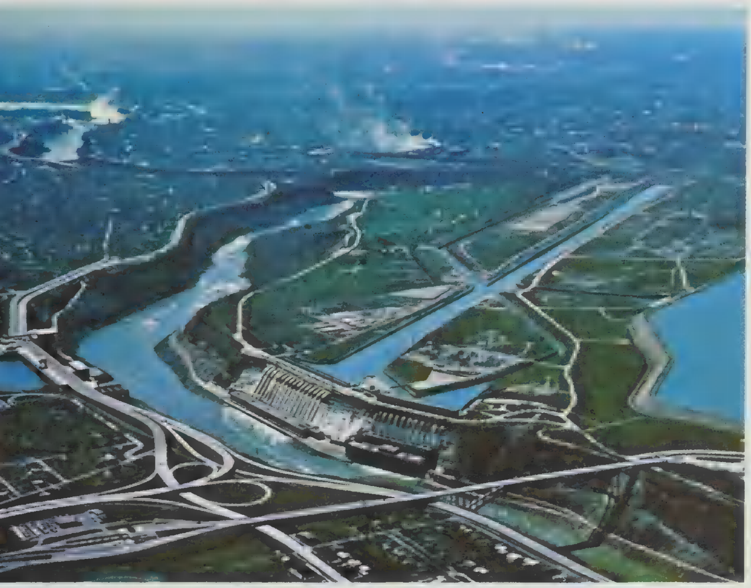
How electricity is made

Your answers to the above questions will give you an idea of the enormous amounts of electricity required in the making of aluminum. To learn why aluminum is made in the Saguenay Valley, it is necessary to have some understanding of how electricity is made.

Electricity is energy, and can be produced from other forms of energy. For example, it can be produced from chemical energy, as in a battery; from light energy, as in a solar cell; or from mechanical energy, as in a generator. A generator consists basically of coils of wire moved inside a circular magnet, the motion producing electricity. Turning a generator is the only way so far discovered of producing large quantities of electricity cheaply.

The cost of producing electricity

The cost of producing electricity is the cost of turning the generator. This can be done in more than one way. At present there are



The water to supply this hydroelectric generating station is diverted from the river above the falls, through the 12-mile canal that you see in this photo and through two tunnels. To avoid reducing the falls to meet peak periods of demand for power, the large reservoir at the right is used. During the day water is drawn from the reservoir; at night the turbo-generators are reversed and used as pumps to refill the reservoir.

two main ways: water power and thermal power. The first uses the natural power of falling water. In the second, a fuel is burned or atoms are split to produce steam under pressure.

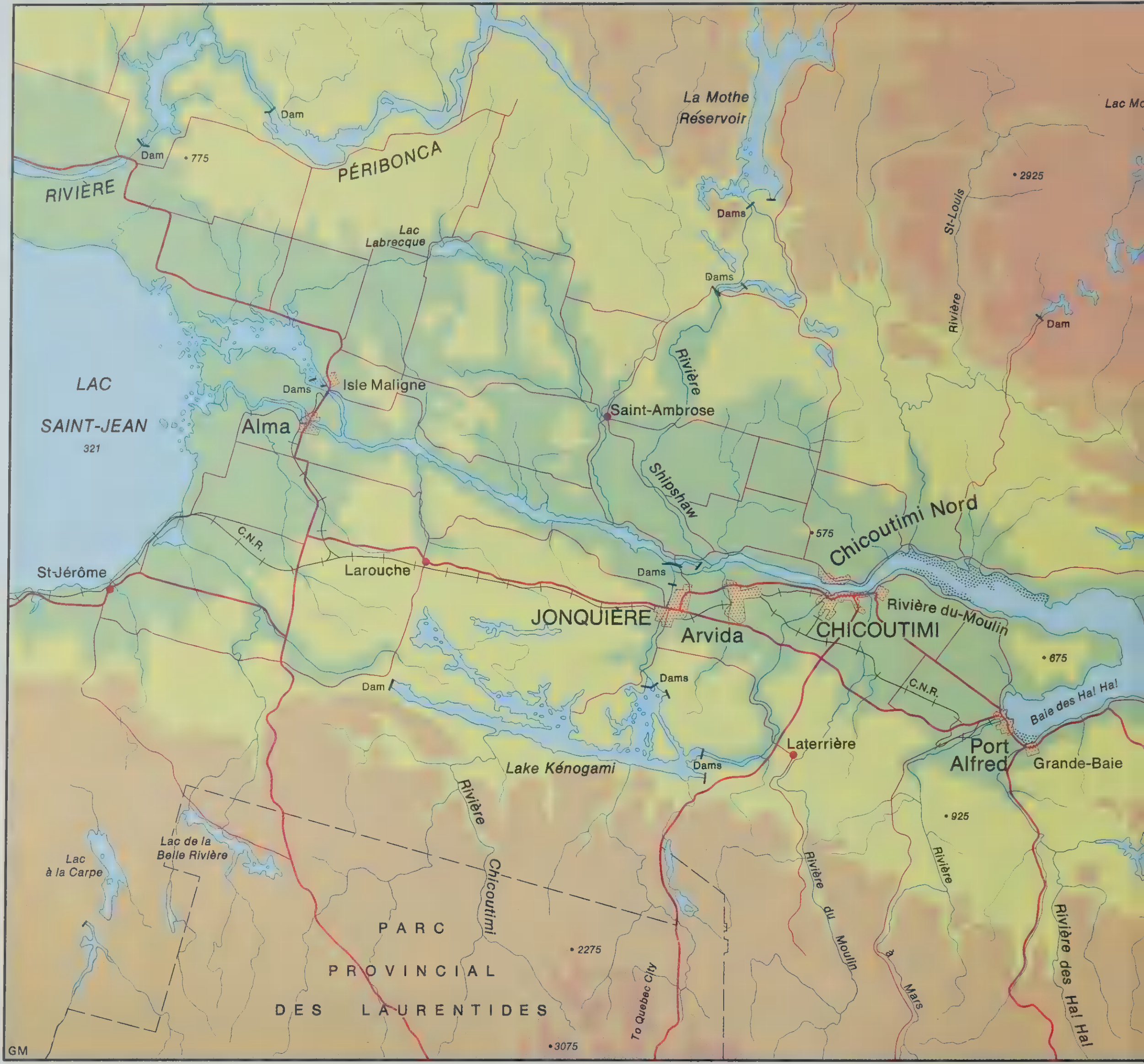
Hydroelectricity

For producing large amounts of electricity over long periods of time, the cheapest method is usually water power. This is the method used in the Saguenay power plants. Electricity produced in this way is called *hydroelectricity.*

Can hydroelectricity be produced anywhere at all? Obviously not: there must be water. There are other requirements as well, however. The Saguenay Valley is ideal for the generation of hydroelectric power. The reason for this goes back millions of years.

Why does a thermal power plant need a steady supply of water?

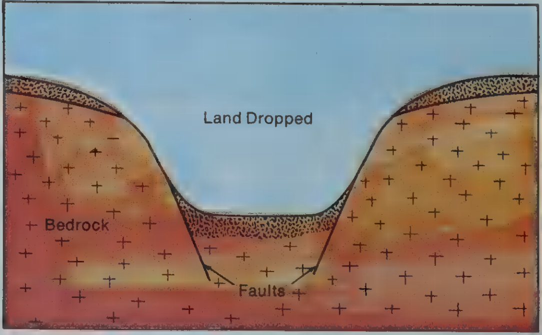
Why does a nuclear power plant not compete with the other two types as yet?

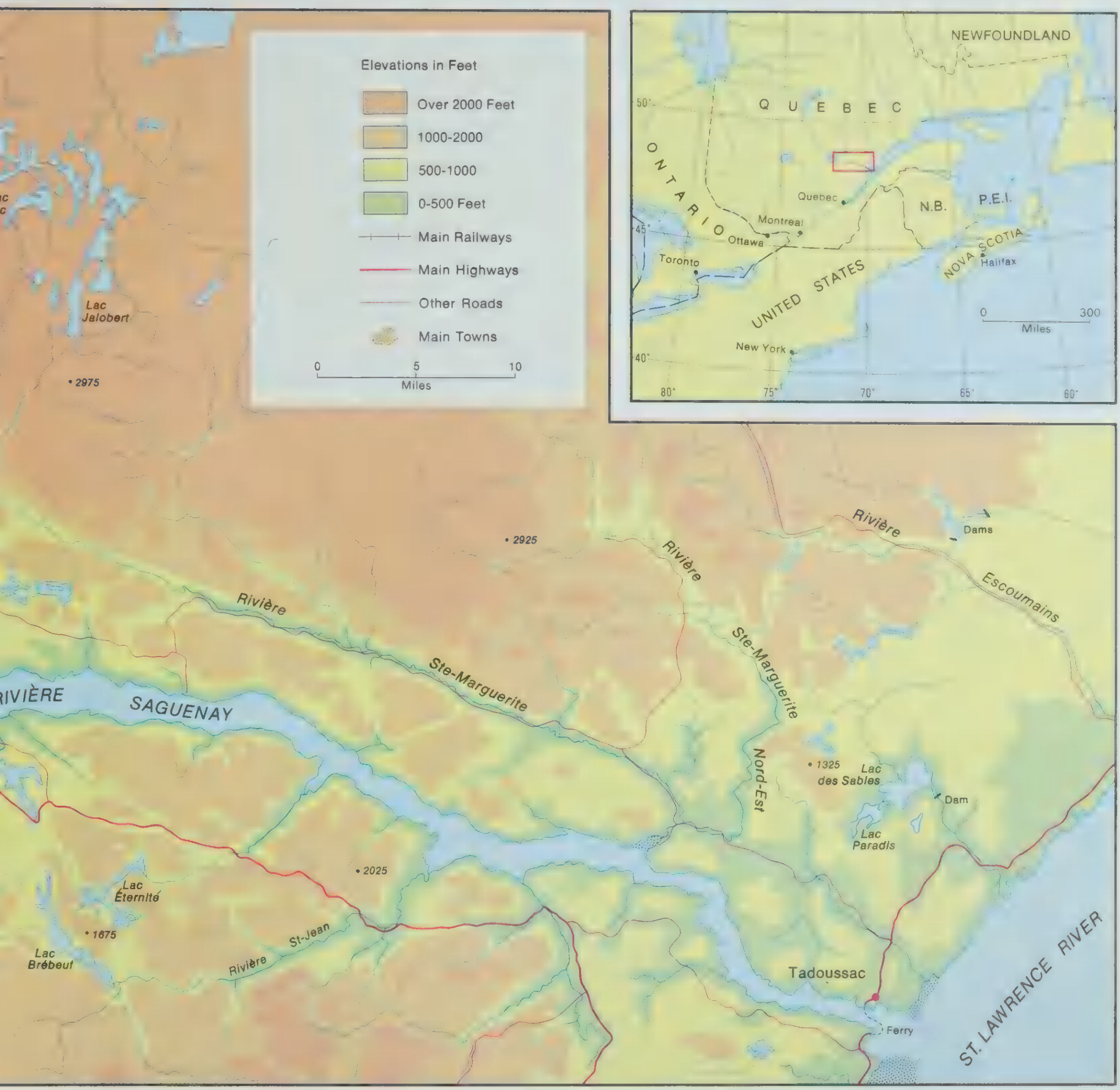


The power dams of the Saguenay region

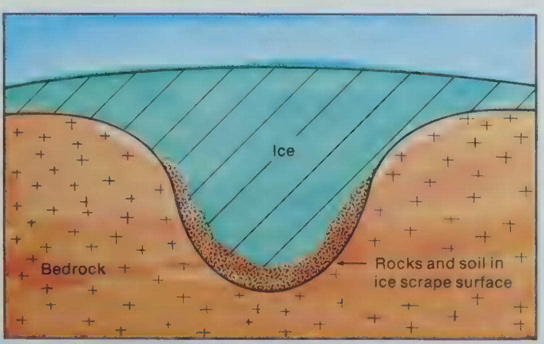
The Saguenay Valley was formed by *faulting*: millions of years ago the earth's crust fractured and, over a period of time, a long block of it slipped downward several hundred feet. One effect of this has already been seen in the fact that the Saguenay River

How the Saguenay Valley was formed. Long blocks of the earth's crust dropped downward millions of years ago. The resulting valley made a natural routeway for glaciers in the last Ice Age.





How would they have changed the valley walls and floor? Suggest two reasons why such a deep, narrow, U-shaped river bed with underlying rock is ideal for damming.

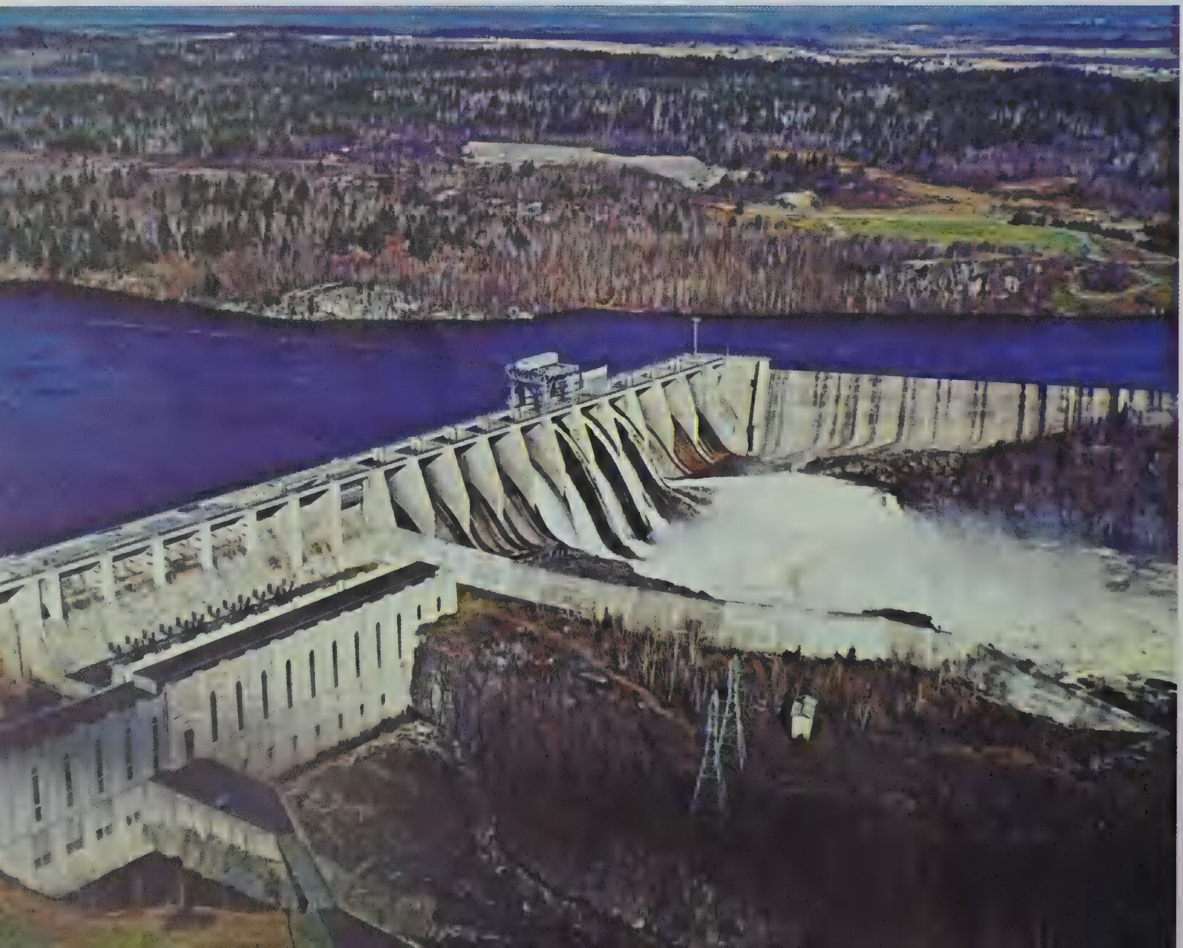


is navigable by ocean-going ships as far up as Port Alfred. Another effect is that between Lakes Peribonka and Manouane and Lake St. John there is a drop of about 1,100 feet, and then from Lake St. John to Arvida the Saguenay River drops another 320 feet. This fact has helped to make possible the development of a vast system of hydro-electric dams.

DO

Discuss the following questions regarding the two main types of electric power installations, hydro and thermal. Which type costs more to build? Which costs more to run? For which type is there a greater choice of location? In what ways might each type involve conflict over land use? Does either type involve undesirable side effects, such as air pollution? Using the results of this discussion, write a summary of the advantages and disadvantages of the two main methods of producing electric power.

Chute-à-Caron. If the reservoir were to be made larger, what would have to be done to the height of the dam? What would happen to the homes in the valley?



DO

1. Study the map on pages 16-17 in conjunction with the diagrams showing how the Saguenay Valley was formed.

a. What color represents the *land* that slipped downward along the fault?

b. What color represents the highest land of the region?

c. Find two areas where very sharp drops occur.

d. On which level are almost all of the towns in the region? Try to suggest reasons for this.

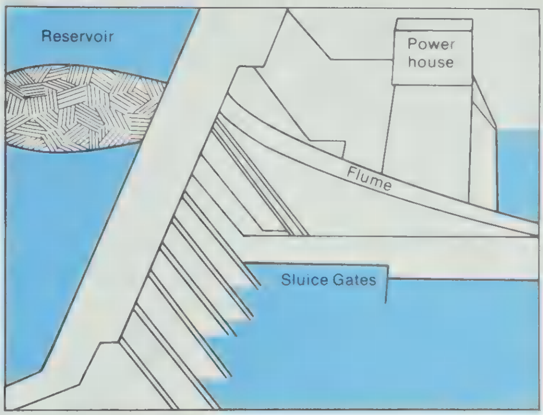
2. Judging from the names of the towns, villages, and rivers, what language did the original settlers speak?

Chute-à-la-Savane. What evidence do you find in this photo of another important industry of the Saguenay Valley?

How electricity is made by water power

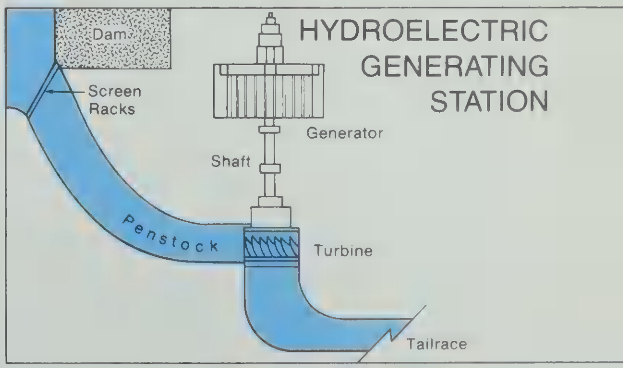
DO

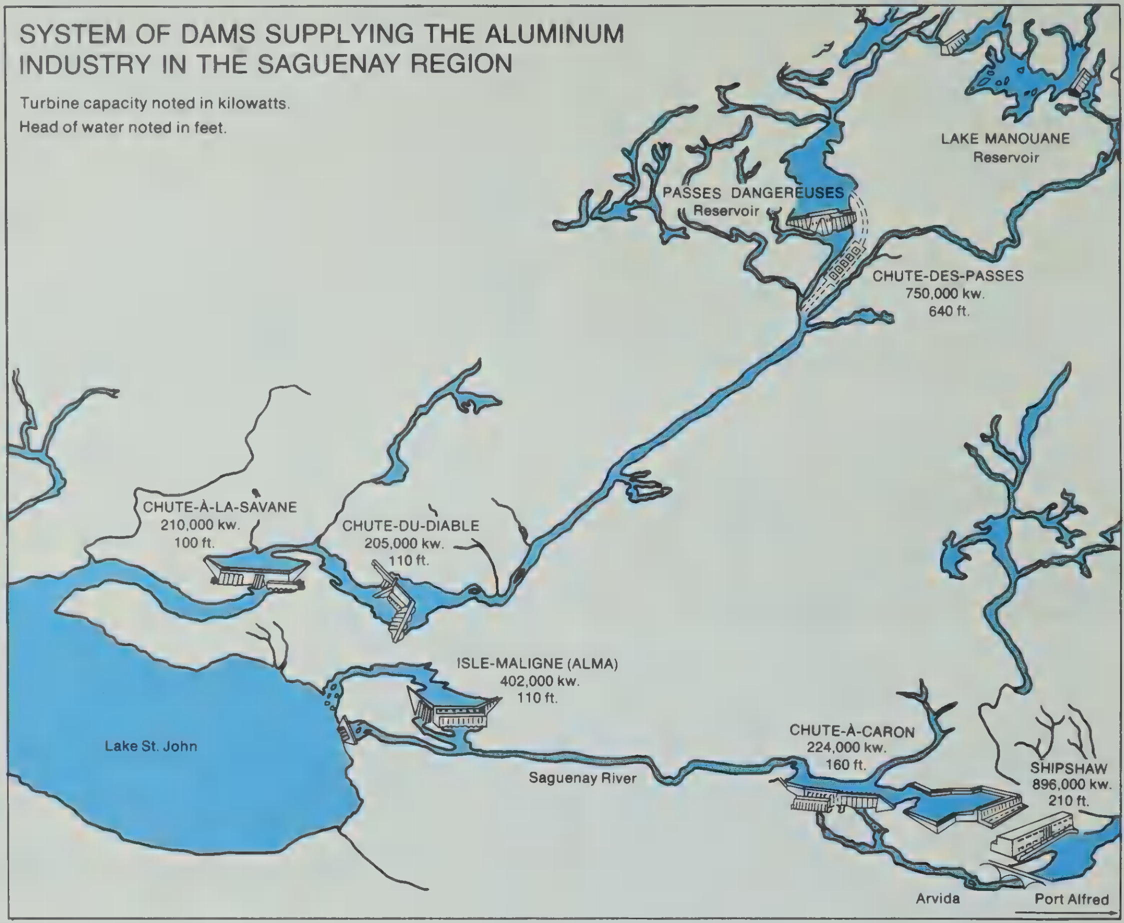
1. Locate Chute-à-Caron on the picture map on page 20. What river is this power installation on?
2. What is the English meaning of the French word *chute*?
3. Draw a diagram of Chute-à-Caron along the lines of the one of Chute-à-la-Savane. Print the following labels in the appropriate places: powerhouse (bottom left), sluice gates (center), spillway (on the right), reservoir, river.
4. What is shown in the diagram of Chute-à-la-Savane that does not appear in your diagram? Study the small picture of this same dam and powerhouse and try to decide what purpose this serves. (A dictionary will help.)
5. What is the purpose of the sluice gates and spillway?



In the diagrams and photos of the dams and powerhouses, notice the distance the water falls from the reservoir to the blades of the turbine. This is known as the *head* of water. The greater the head, the stronger the force with which the water strikes and turns the turbine blades. The *volume* of water flowing in the river is another important factor. A large volume of water will turn more generators than a small volume. A large river with a good drop is therefore more valuable for hydroelectric production than a small river with a similar drop.

Hydroelectric generating station. The water passes from the reservoir, through the penstock, to the turbine blades. The turbine is connected to the generator above by a metal shaft. As the turbine turns, the generator turns, producing electricity. What is the purpose of the screens?

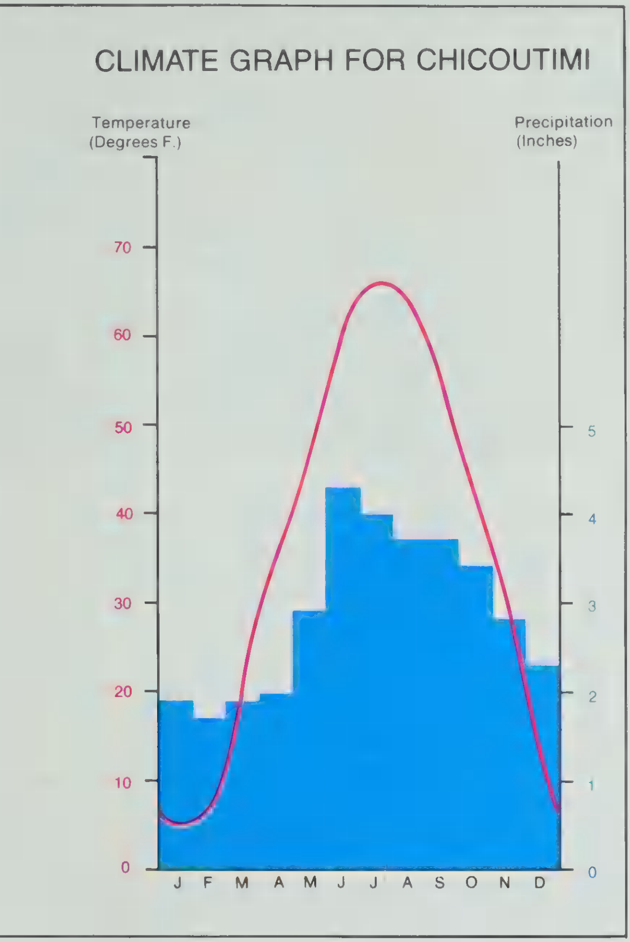



SYSTEM OF DAMS SUPPLYING THE ALUMINUM INDUSTRY IN THE SAGUENAY REGION
Turbine capacity noted in kilowatts.
Head of water noted in feet.
LAKE MANOUANE Reservoir
PASSES DANGEREUSES Reservoir
CHUTE-DES-PASSES 750,000 kw. 640 ft.
CHUTE-À-LA-SAVANE 210,000 kw. 100 ft.
CHUTE-DU-DIABLE 205,000 kw. 110 ft.
ISLE-MALIGNE (ALMA) 402,000 kw. 110 ft.
Lake St. John
Saguenay River
CHUTE-À-CARON 224,000 kw. 160 ft.
SHIPSHAW 896,000 kw. 210 ft.
Arvida
Port Alfred

Here you see the dam system as a whole. In addition to the reservoir behind each individual dam, there are three large reservoirs for the system: Lake Manouane and Passes Dangereuses, both greatly increased by dams, and Lake St. John, a natural reservoir of some four hundred square miles. The system cost hundreds of millions of dollars; but, since the Arvida plant alone uses about six billion kilowatt-hours in a year, a saving of one-tenth of a cent per kilowatt-hour means a saving of six million dollars per year!

DO

1. From the picture map, write down the figure for the head of water for each of the three dams above Lake St. John (Chute-des-Passes, Chute-du-Diable, and Chute-à-la-Savane) and total them to see how much of the 1,100-foot drop has been harnessed.
2. Do the same for the three dams on the Saguenay River. Study the course of the river to find out why this total is greater than the 320 feet that the Saguenay drops from the lake to Arvida.
3. What is the advantage of building a dam near a waterfall or rapids rather than on a quiet stretch of water?



Climate is important

DO

1. Look at the precipitation part of the climate graph.
a. What does "precipitation" mean?
b. How is monthly precipitation shown on the graph?
c. Some climates have a *dry season*, with almost no precipitation, and/or a *wet season*, when much of the total annual precipitation falls within a few months. Has the Saguenay Valley such a dry season or a wet season?
2. How can the engineers regulate the head of water in different parts of the year: at each individual dam? for the system as a whole?
3. Look at the temperature part of the climate graph.
a. Which months have average temperatures below freezing (32°F)?
b. What effect would this have on the water supply to the hydro dams?

DO

Some recent hydroelectric power projects in Canada are the Gardiner Dam in southwest Saskatchewan, the Manicouagan-Outardes complex in northern Quebec, Churchill Falls in Newfoundland (Labrador), and the W.A.C. Bennett Dam in the Peace River country, in British Columbia. Collect information on each of these projects, noting especially any way in which they may differ, in purpose or construction, from the hydroelectric installations of the Saguenay.

Planning the location of the aluminum smelter

Electricity is the only known means of separating any large quantity of aluminum metal from alumina, and water is usually the most economical method of producing this power. The system of hydroelectric dams in the Saguenay Valley was constructed at great cost (several hundred million dollars) after the region had been selected as the site of a new aluminum smelter in the 1920's. The planning, construction, and expense necessary before the Arvida smelter produced its first ingot are an indication of the great value that aluminum has in the eyes of man.

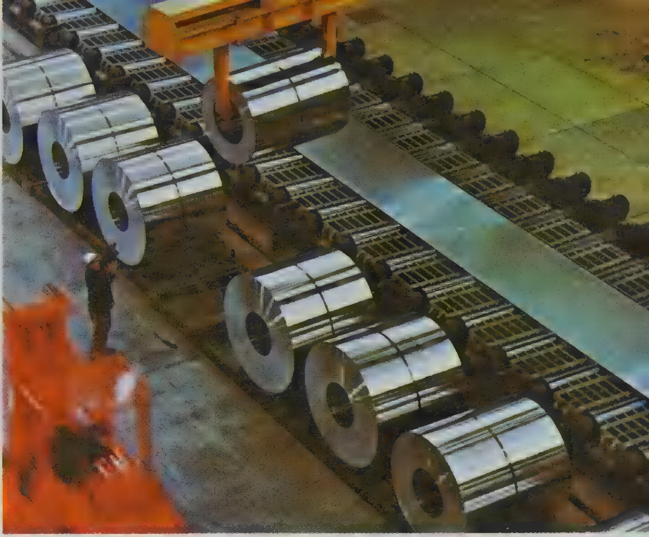
DO

1. Suppose you are a planner making recommendations for the site of an aluminum smelter. Show how well the Saguenay Valley meets three basic requirements of cheap power, port facilities, and flat land for the smelter site.

2. Study the diagram of the Kemano tunnel along with a map of the coast of British Columbia, and assess Kitimat as the site of an aluminum smelter, using the three basic requirements.

3. a. What route would be taken by ships carrying alumina from Jamaica or Guyana to Kitimat?

b. Compare this distance with the distance from Guyana to Port Alfred.



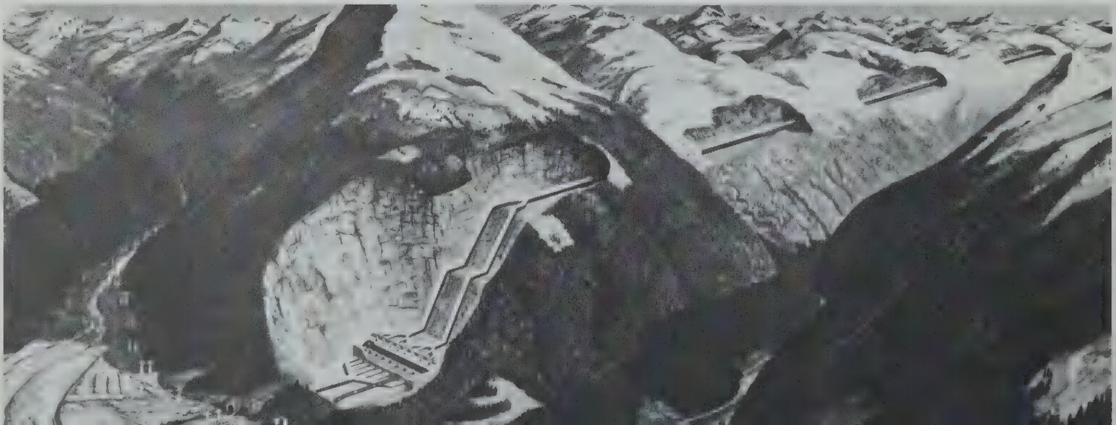
The secondary manufacturing stage is represented by these coils of aluminum sheet. A large new rolling mill soon to be built at Arvida will greatly increase Canadian output at this stage of the industry. What is the advantage of having the mill near the smelter?

From Bauxite to Finished Product

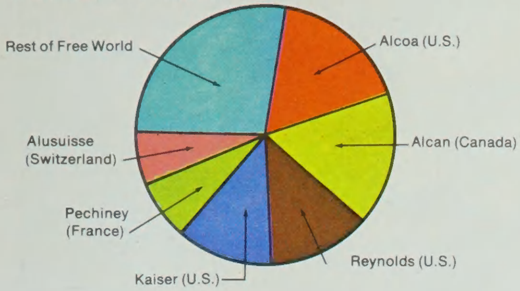
Aluminum begins as bauxite, which must be dug out of the ground in open-pit mines in some tropical countries. This activity is classed as a *primary resource industry* or an *extractive industry*. The bauxite is refined into alumina. Either the bauxite or the alumina is transported to a site that has access both to immense quantities of electricity and to the markets of the world. The alumina is smelted into aluminum ingots of various weights and shapes. This twofold stage of refining and smelting is classed as a *primary manufacturing industry*. The next stage of activity is to alter the shape of the aluminum ingot into a product or a part of a product by rolling, casting, extruding, and various other processes. This stage of activity is classed as a *secondary manufacturing industry*.

Canada's part in the aluminum industry is very largely at the primary manufacturing level. And the only resource the Saguenay

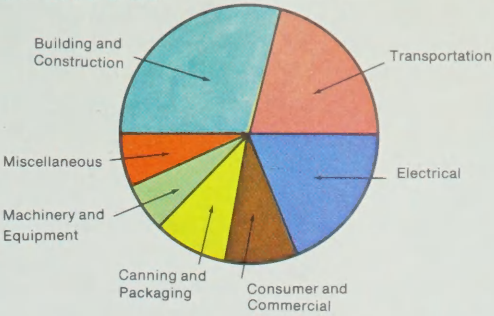
DuBose Tunnel at Kemano. The Nechako River used to flow eastward; now, backed by the Kenney Dam, it flows westward, dropping half a mile through this tunnel to generate power for the aluminum smelter at Kitimat.



MAIN PRODUCERS OF PRIMARY ALUMINUM



CANADIAN USAGE OF ALUMINUM, BY END USE



Valley supplies for the smelting of the metal is water power, which is a *renewable resource.*

Many of our natural resources are non-renewable: that is, they will sooner or later be completely used up. Coal mines will run out of coal; all the oil will one day be pumped out of the ground. Forests, on the other hand, can be renewed through reforestation, and lakes can be restocked with fish. With good conservation practices, water power will renew itself as long as rain and snow continue to fall. Long after the resources from our mines and oil wells have been used up, our water resources will still be available to generate valuable hydroelectricity.

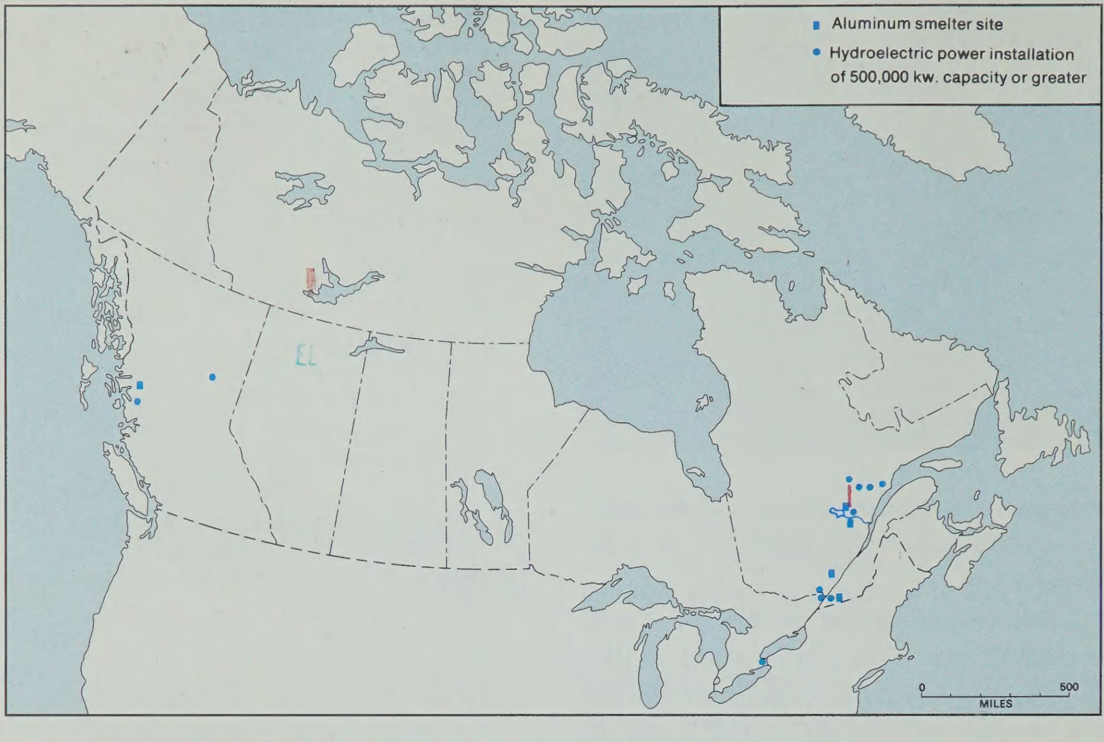
Aluminum in Our World

DO

1. Write a paragraph explaining why Europe and North America produce more aluminum than do South America, Africa, and Asia.
2. Can you foresee a time when this situation will change? Explain. (A hint: since this graph was compiled, a £46 million smelter has started production in Ghana.)
3. Make a list of examples for each use of aluminum, as shown in the graph.

DO

1. Make a list of other renewable natural resources found in Canada.
2. Name some other non-renewable natural resources that will one day—perhaps centuries from now—be used up.
3. Using steel-making as an example of another metal industry, and paper-making as an example of a non-metal industry, list the different stages of activity under the following headings: extractive industry, primary manufacturing industry, secondary manufacturing industry. Give the location of each stage. (Do this exercise in chart form if you like.)


■ Aluminum smelter site
● Hydroelectric power installation of 500,000 kw. capacity or greater
0
500
MILES

DO

1. With reference to the map, suggest a reason why aluminum smelter sites and hydroelectric installations should be shown on the same map. Why are hydroelectric installations shown near every aluminum smelter, whereas not every hydroelectric installation has an aluminum smelter nearby?

2. It is quite possible that in the not too distant future the cost of generating electricity by nuclear power will come down to a level that competes with hydroelectricity. Discuss the effects on Canada's aluminum industry if this should come about.

A filmstrip, *Aluminum* (36580), is available from the National Film Board of Canada.

Credits

Ginn and Company thanks Alcan Aluminium Limited for its generosity in providing information and photographs. Photographs were also obtained from Ontario Hydro (all on page 15) and from National Aeronautics and Space Administration, Washington (page 13). Maps (pages 4 and 16-17) are by Geoffrey Matthews.

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